DEFINITE PROJECT REPORT
WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

SECTION 206
LAKE BELLE VIEW
AQUATIC ECOSYSTEM RESTORATION PROJECT

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APPENDIX F
GEOTECHNICAL CONSIDERATIONS

1. PURPOSE

The purpose of the Lake Belle View Aquatic Ecosystem Restoration Project is to evaluate the Federal interest in the improvement of aquatic habitat and the enhancement of wetland habitat in Lake Belle View and the nearby Sugar River. This appendix presents site conditions and specific geotechnical analyses relevant to the study. To support the preparation of this appendix, personnel from the Rock Island District's Engineering Division, Geotechnical Branch, reviewed literature, obtained soil borings, performed laboratory analysis and interpretation, and provided geotechnical analyses and recommendations.

2. LOCATION

Lake Belle View is a shallow millpond located approximately 20 miles southwest of Madison on the Sugar River in the Village of Belleville, Dane County, Wisconsin. The Sugar River watershed above Lake Belle View is approximately 172 square miles. Two river channels (Sugar River and West Branch Sugar River) converge several miles upstream of Lake Belle View. The Sugar River watershed is highly agricultural and experiencing rapid urban growth. The project area includes a lake, floodplain forest, and various wetland communities totaling 133 acres. Bordering the project area are a park, residences, roads, and farmland.

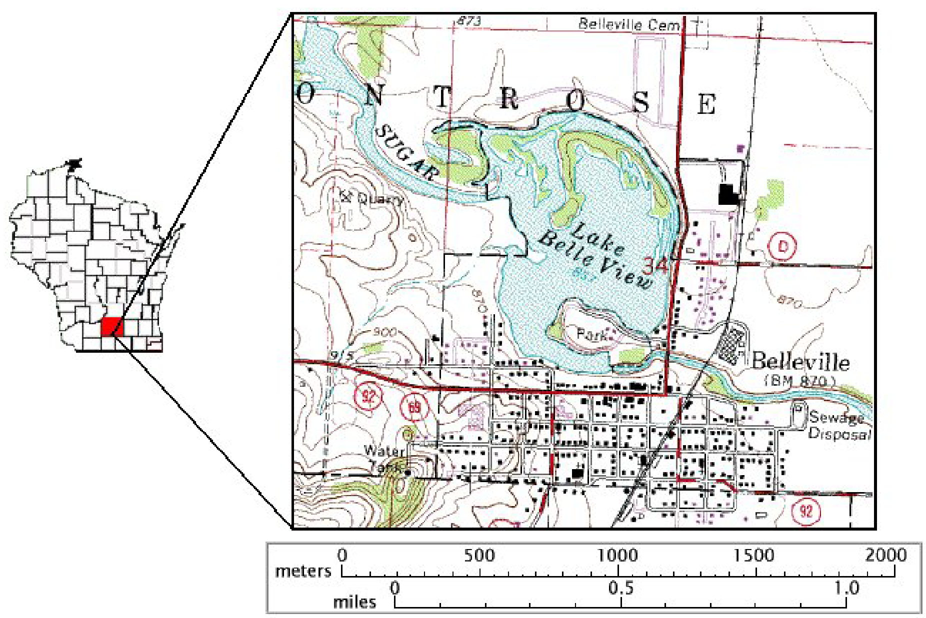

Figure F.1. Location maps.

3. PROJECT FEATURES

Potential features that were evaluated in the feasibility study included sediment removal, chemical treatment, river diversion, wetland restoration/enhancement, island creation, periodic drawdown, fish passage structures, and rough fish control. Sediment removal would improve water quality and increase lake depths. Chemical treatment of the lake sediments would act to bind the phosphorus, improving the water quality of the lake. River diversion would create separation of the lake and river channel, which would improve both water quality and fish passage. Directing the river into a channel would allow it to maintain its velocity and not drop sediments and nutrients into the lake. It would also reduce the warming effect that the lake has on the river and potentially extend the cool-water fishery downstream. The reduction of sediment and nutrients entering the lake would benefit water quality as well as the warm-water fishery. River diversion would be accomplished by separating the Sugar River from Lake Belle View by means constructing a diversion embankment.

Wetland enhancement would provide multiple benefits to water quality and fish and wildlife by creating depth diversity through dredged material placement. The existing forested wetland and wet prairie/sedge meadow could be enhanced by the creation of additional wetlands throughout the lake. A diversity of habitat types would be beneficial to the fishery and to the wildlife utilizing the area. Wetlands also have the ability to remove nutrients from the water and thus improve water quality. Urban runoff enters the lake from the west and creation of wetlands would provide a "filter" for that runoff prior to its entering the lake and river.

Island creation within the lake would improve water quality by decreasing turbidity. An ancillary benefit of this feature would be the beneficial use of dredged material. A periodic drawdown of 6 inches would promote emergent vegetation growth in approximately 25% of the lake area, which would reduce turbidity, increase aquatic and wetland habitat, and reduce potential algal blooms (UWWRM 1995). Fish passage structures would increase aquatic diversity by facilitating the upstream movement of many fish species. This is significant due to Lake Belle View's location in the headwaters of the Sugar River. Rough fish control would improve the water quality of the lake by reducing the number of rough fish, such as carp, in the lake.

During preliminary screening of the proposed features, the chemical treatment and island creation features were dropped from further consideration. This appendix will further develop the proposed river diversion, wetland enhancement, and sediment removal features.

4. GEOLOGY

Lake Belle View straddles the border between two distinct geologic regions: the "driftless area" and the glaciated area of Dane County (Mickelson 1983).

4.1 Driftless Area

Glaciation played a major role in shaping the present landscape of all but the southwest corner of Dane County, known as the driftless area. More than half of the Lake Belle View watershed lies within this region. Due to erosion and the lack of glaciation, deep-cut valleys and exposed sandstone and dolomite bedrock characterize the driftless area. Approximately 10,000 years ago, the general form of streams in the driftless area was altered from a shallow, braided pattern with several channels to the narrow, single channel shape such as the present-day Sugar River (Mickelson 1983). The majority of the fine-grained material currently in driftless area valleys was deposited during the last 10,000 years. As the glaciers retreated, large volumes of loess, a winddeposited sediment primarily composed of silt-sized quartz particles, blanketed the area. The loess in Dane County is usually less than 3 feet thick and generally overlies bedrock in the driftless area. Because of its small grain size, loess is easily eroded from slopes into valleys. Human settlement and land clearing in the 1800's increased upland erosion, especially in the driftless area. Slope runoff deposited a thick layer of fine-grained material over the sands and gravels of former floodplains (Mickelson 1983). The ongoing processes of flooding and stream meandering continue to deposit and erode sand and silt in driftless area floodplains.

4.2 Glaciated Area

The predominant glacial deposits in Dane County, such as the Johnstown Moraine northeast of Lake Belle View, are from the Woodfordian or late Wisconsin age. This last glaciation deposited materials that are approximately 14,000 to 20,000 years old. The oldest surficial glacial deposits in Dane County, identified as pre-Woodfordian ground moraine, are located directly east and north of Belleville. Ground moraine is a relatively level or rolling till surface. Till is unstratified material, with a large range in grain size. The Johnstown Moraine, a ridge composed primarily of till that delineates the farthest extent of glaciation in Dane County, extends into the eastern portion of the watershed. While the glacier was present at the Johnstown Moraine approximately 14,000 years ago, large volumes of meltwater were produced. The Sugar River was one of the main glacier meltwater outlets. Large quantities of outwash containing a wide range of particle sizes were carried by the meltwater into the Sugar River Valley and deposited in relatively well-sorted, flat layers. As the distance from the glacier increased, the particle size of deposited material decreased. The outwash layer in the vicinity of Lake Belle View is relatively flat and composed primarily of sand with a few small pebbles. A layer of loess usually overlies the outwash.

5. SURFICIAL SOILS

Parent materials, climate, plants and animals, topographic relief, and time determine the development of soils. Since the last glacier retreated, surface soils in the Lake Belle View watershed have developed from the weathering of loess and minerals in glacial deposits. Decomposed prairie and open woodlands vegetation has added organic matter. Soil surrounding the immediate lake area is characterized as a silt loam as classified in the following series: Marshan Series, Plano Series, Batavia Series, Kegonsa Series, Meridian Series, and Alluvial Land. These soils are moderately deep to deep, poorly drained to well drained, nearly level to gently sloping soils found on low to high benches and outwash plains. Most were formed in loess deposits, loamy outwash, or sandy outwash (USDA 1978).

6. SUBSURFACE EXPLORATION

Subsurface exploration was done to obtain foundation and borrow material samples for determination of their engineering characteristics. All subsurface exploration completed by the Rock Island District was performed in accordance with U.S. Army Corps of Engineers Manual EM 1110-1-1804.

Personnel from the Rock Island District's Geotechnical Branch performed subsurface exploration during two different time periods as the project scope evolved. Nine offshore borings were taken in February 2000 and four borrow area borings were taken in April 200 also was done on shallow lake sediments in accordance with ASTM D-2573 in April 2002. The boring and vane shear locations are shown on plate F-1 and Rock Island District boring logs are shown on plates F-2 and F-3. Additional exploration is planned following selection of the preferred alternative, and prior to preparation of construction documents, in order to provide detailed subsurface information in specific areas.

MSA Professional Services, Incorporated, installed four observation well nests in May 1999 (MSA, 1999). The observation well nest locations are shown on plate F-4 (W-1, W-2, W-3, and W-4). Observation well nest details for W-1, W-2, W-3, and W-4 are shown on plates F-5 and F-6.

7. TEST RESULTS

Soil testing for borings LB-00-01 through LB-00-09 and LB-02-01 through LB-02-04 included moisture contents, Atterberg Limits, % finer than the #200 sieve size, and vane shear. The results of the laboratory testing are listed with each individual boring log as shown on plates F-2 and F-3. All laboratory soil tests were done in accordance with EM 1110-2-1906. The vane shear testing was done on the sediments ranging in depth between 1 and 3 feet and in accordance with procedures outlined in ASTM D2573 - Standard Method for Field Vane Shear Test in Cohesive Soil. A plasticity index correction factor was also applied as described by Duncan (1989). Vane shear test results are shown below in Table F.1.

TABLE F.1			
LAKE BELLE VIEW VANE SHEAR			
ASTM D2573		$Su = (3T)/(28\pi r^3)$	
PI correction factor=		0.85	
LOCATION	DEPTH (ft)	T (in-lb)	S_u (psf)
VS-1	2	225	138
VS-2	3	200	123
VS-3	1	250	153
VS-4	2	370	227
VS-5	1	340	209
VS-6	2	275	169
VS-7	3	275	169
		AVG= 170	

8. STRATIGRAPHY AND GROUNDWATER

The surface of the sediment within Lake Belle View varies between approximate elevations 857.0 and 855.0. Borings LB-01-01 through LB-01-09 were taken in the lake sediment. They indicate a layer of clay with varying thickness (between 2 and 7 feet), varying organic content, varying water content (between 28% and 103%), and varying sand content (between 0% and 49%). The clay lake sediments are generally soft in consistency. A detailed discussion of lake sediment characteristics is provided by MSA (MSA 1997). The reference also delineates the location of the “hard bottom,” or top of sand foundation, within the lake.

Borings LB-02-01 through LB-02-04 were taken in the proposed borrow area located immediately west of Lake Belle View. The surface of these borings varies between approximate elevations 868.0 and 863.0. These borings indicate a surface layer of medium to lean clay ranging in thickness between 3 and 8 feet. The clay was generally stiff in consistency, and water contents were generally closer to the plastic limit than to the liquid limit.

MSA Professional Services, Incorporated, performed study and analysis of site stratigraphy and both regional and local groundwater conditions at Lake Belle View. Their findings are described in their June 1999 report entitled, "Lake Belle View Restoration Project – Lake Evaluation Studies Progress Report, Belleville, Wisconsin." The following excerpts are taken from the Executive Summary of the MSA report:

> "The hydrogeologic evaluation examined the subsurface physical setting near the lake to provide information on the potential for groundwater contributions to the existing lake…. It included a regional evaluation, a data acquisition and monitoring program, and a hydrologic assessment…."
>
> "The regional evaluation suggests the Lake Belle View area has been greatly influenced by past glacial events, and most of the unconsolidated deposits beneath the soil layer were transported and deposited by glaciers or deposited by glacial meltwater streams. There is a thick layer of unconsolidated glacial outwash and till, averaging 60 to 70 feet thick in the lake vicinity, which overlies bedrock. A regional decline in groundwater elevation toward the lake from the northeast, northwest, and southwest suggests that the lake could be fed from groundwater from much of the surrounding area. The data acquisition program installed four observation well nests in different areas around the lake, and characterized the subsurface geology in those areas. Water levels were monitored in April and May of 1999 to assess the local water table configuration near the lake and characterize the near-surface geologic deposits…"
>
> "The data acquired showed that unconsolidated deposits in the lake vicinity consist of a thin layer of topsoil and in some areas brown and gray mottled clay and clayey sand, overlying brown and tan fine to coarse sand with gravel. The sand and gravel deposit is saturated and represents alluvial deposits and glacial outwash deposits in the Sugar River Valley. The sand and gravel deposits are the primary water bearing formation near the lake, and were in excess of 42 feet in thickness on the east side of the lake and thinner on the west side of the lake. Underlying the sand and gravel deposit was a gray fine silty sand and gray clayey sand with gravel. This deposit is the glacial till formation. The glacial till is a lower permeability soil unit with a considerable clay and silt content, which will limit the flow of groundwater through the layer."
>
> "Groundwater flow directions and elevation contours were developed from the water level data. On the north and northeast side of the lake, groundwater flow is southwest toward the lake. On the west side of the lake, groundwater flow is eastward toward the lake. Gravity flow from the water table to the lake appears to be occurring on both the east and west sides. Relatively low upward vertical gradients were observed in the two well nests located on the east side of the lake. This suggests that conditions are present for the upward movement of groundwater through the subsurface materials, but the gradient is relatively small in this area. Higher vertical gradients were observed on the west side of the lake and artesian conditions with water levels above ground surface were observed at several wells. These wells were screened in the glacial till and bedrock formations, and indicated strong upward vertical gradients are present in these strata at this well nest location; however, the presence of the low permeability glacial till overlaying the sandstone likely prevents significant water movement from the sandstone to the lake. The surficial aquifer that has the greatest

potential for hydraulic connection to the lake is the sand and gravel alluvial outwash deposit state where this deposit is located. Finer grained sediment on the lake bottom might slow groundwater flow in the lake. Assuming that all fine grained material was removed and the sand and gravel were in contact with the lake, a flow net and equipotential contours were used to estimate a groundwater inflow of 4.45 acre-ft/day…."

MSA's hydrogeologic cross section developed from data taken from the four observation well nests is shown on plate F-7. The flow net developed by MSA is shown on plate F-8. MSA also performed baildown hydraulic conductivity testing in their observation wells (MSA 1999). Calculations done using the baildown tests resulted in an average hydraulic conductivity of 4.5 x 10^{-1} cm/sec. MSA's groundwater analysis assumptions, computations, and conclusions were reviewed. MSA assumed no upward flow of groundwater in their analysis, and an average lake depth perpendicular to the flow shown in their flow net of 4 feet. MSA's data acquisition, analysis, and results are considered reasonable. The maximum total lake inflow will be assumed to be 4.45 acre-ft/day. However, lower inflows can be expected since less than 100% removal of the lakebed fine sediment is proposed. Additional discussion of stratigraphy and groundwater characteristics relevant to specific project features are provided in Section 9.

9. PROJECT FEATURES DESIGN

9.1 General

The features that require geotechnical design include river diversion, wetland enhancement, and sediment removal. These three basic features are closely related by material utilization and balance considerations, as well as construction sequencing issues. Construction of selected project features will proceed in the following generalized sequence: drain Lake Belle View, utilize conventional earth-moving equipment to rock-stabilize diversion berm foundation where necessary, utilize conventional earth-moving equipment to build confined disposal facility (CDF) and river diversion berms, impound Lake Belle View, utilize "high-solids" and/or conventional hydraulic dredging methodology to move upper fine-grained sediments from dredged areas to wetland enhanced areas, utilize conventional hydraulic dredging methodology to move lower sands from dredged areas to the CDF, place erosion protection stone in designated areas, drain Lake Belle View, utilize "low ground pressure" earth-moving equipment as necessary to evenly spread fine-grained dredged material previously placed in wetland enhanced areas, build riffle structures and add additional erosion protection stone as necessary, and fill Lake Belle View.

9.2 River Diversion

River diversion would be accomplished by building a diversion berm designed to channel the Sugar River around either the east or the west side of Lake Belle View. The eastern diversion alternatives (most likely the preferred alternative) would include adjacent Sugar River channel deepening. The berm would be constructed using the previously described competent clay taken from the borrow area located immediately west of Lake Belle View.

According to Wisconsin Administrative Code Ch. NR 333 (Dam Design and Construction), the proposed diversion berm for the eastern diversion alternatives must be classified as a dam due to its height and the amount of water it impounds. As such, it is subject to standards for stability. In accordance with NR 333, the dam must be designed by a licensed Professional Engineer (State of Wisconsin), and the design must be submitted to Wisconsin dam safety personnel for review and approval. As an initial step in that process, stability and seepage analyses will be performed as part of this appendix.

Adjacent borrow would be the obvious choice for construction of the eastern diversion berm, especially since eastern diversion alternatives also include channel deepening. However, since the fine-grained material adjacent to the berm location is soft and contains appreciable organics, it is considered unsuitable for use in constructing a "dam." Also, the fine material that would be removed from the Sugar River channel as part of the eastern diversion alternative would be needed to enhance the wetland areas. The use of underlying sand and gravel is not considered for any eastern diversion berm alternative due to the through-seepage and erosion concerns associated with sand structures.

The geotechnical concerns for construction of any eastern diversion berm are foundation and slope stability, river current erosion resistance, and seepage stability. The fine-grained sediment lying beneath proposed diversion berm locations has historically remained soft, even after Lake Belle View has been drained for several months. This is due in part to the slow drainage characteristics of the in situ fine-grained sediment and in part to the location of the water table. The construction sequence would include foundation rock-stabilization of any of the diversion berm alternatives as necessary to allow conventional earth-moving equipment to proceed with berm construction. The rock is expected to displace the upper fine-grained "soft" sediment to depths approaching the surface of the underlying sands and gravels. The rock stabilization would be placed on the downstream side of the diversion berm, as shown in plate F-9, so that a competent through-seepage cutoff is achieved between the upstream portion of the diversion berm and the underlying foundation fine sediments. The depth of the "soft" sediment varies between 2 and 4 feet over the "footprint" of the proposed diversion berms, and the cohesive strength of this sediment can be assumed to be less than 200 psf (see the vane-shear strength data, Table F.1). Since much of the upper "soft" sediment would be displaced by the rock stabilization and the underlying sediments are composed of sand, long-term consolidation settlement is considered negligible.

As previously described, the diversion berm would be constructed using cohesive borrow material taken from the borrow site lying adjacent to, and immediately west of, Lake Belle View. The diversion berm would be built with 3H:1V slopes. The borrow would be placed in lifts and compacted to 95% maximum density at plus or minus 2% optimum water content.

The correlation presented in Figure F.2 represents a compilation of data from normally consolidated river valley clays found within the Rock Island District. The average water content of the materials found in the designated borrow area adjacent to Lake Belle View is approximately 28%. From Figure F.2, the undrained strength of these lean to medium clays will be taken as 400 psf. The strength of the underlying sands and gravels will be assumed to be 34 degrees angle of internal friction.

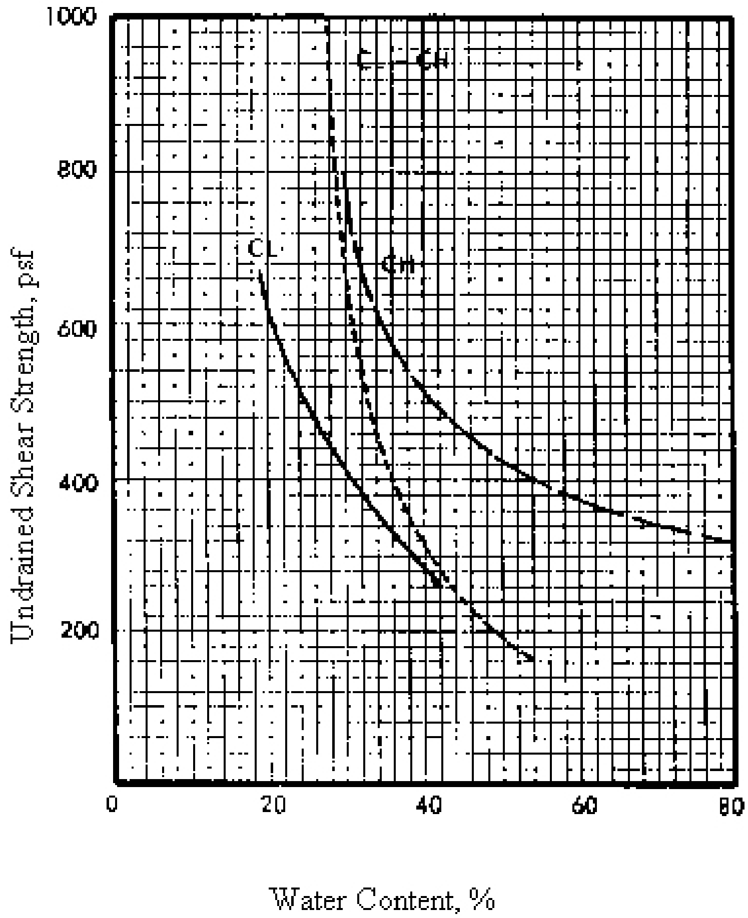

Figure F.2. Water content versus undrained shear strength.

The most critical diversion berm section was assumed to be at the downstream end of the project area (approximate STA 5 + 00) where the height of the berm and the head difference across the berm are the greatest due to the greatest extent of Sugar River channel excavation. The diversion berm/channel excavation system was analyzed here for slope stability in accordance with EM 1110-2-1902. The slope stability package UTexas4 (Wright 1999) was used to determine sliding factors of safety for the Lake Belle View diversion berm and foundation. The UTexas4 program was run in the search mode and numerous failure surfaces were examined, but the model scenario depicted on plate F-9 is considered to be the most critical. This model includes a piezometric surface located at the slope surface and no water in the channel, both conservative assumptions. The analysis resulted in a sliding factor of safety of 1.58. Any strength gained from foundation stabilization with rock was ignored for this analysis. The additional global stability provided by the filter blanket (described below) also was ignored.

Groundwater seepage through the diversion berm foundation sands is expected to exit on the slope of the excavated Sugar River channel. The channel slope excavation must be designed and protected in a way that resists both through-seepage forces and Sugar River water current attack. Bankline protection designed to resist water current attack will not be addressed in this appendix (see Appendix H - Hydrology and Hydraulics).

The diversion berm/channel excavation system exhibits seepage characteristics similar to the sand levee through-seepage that occurs at high Mississippi River stages for numerous agricultural levee projects. The Rock Island District has adopted a design that dictates a 5H:1V landside slope for these sand levees. This design has proven reliable over many years and high water events. It has also been shown analytically (Schwartz 1976) that a 5H:1V landside slope with steady seepage exhibits sliding stability safety factors of approximately 1.5. For additional reliability, it is recommended that a stone filter blanket be constructed on the sand portion of the Sugar River channel excavation. The filter blanket should consist of a 2-foot-thick layer of 400-lb top size erosion protection stone. The stone should be underlain with a 1-foot-thick bedding layer that is designed to prevent sands from migrating through the blanket.

9.3 Wetland Enhancement

As discussed above, the wetland areas adjacent to Lake Belle View would be enhanced by adding fine-grained dredged material. Fine-grained material would be taken from the upper 2 to 7 feet in the areas depicted in the main report drawings and placed in the designated wetland areas. Sands and gravels are found below the 2- to 7-foot-depths (see MSA 1997) and are considered inappropriate for placement in wetland areas. It is anticipated that the fine-grained material would be moved by some dredging methodology. The distance between the dredged areas and the wetland placement areas would presumably exclude mechanical dredging as a method. Some type of "high solids" dredging method would be the most likely method of placement within the wetland sites. Conventional hydraulic dredging of fine material for wetland enhancement is unlikely, since confined disposal facility construction is not desirable at the wetland sites. After the fine-grained material has been placed, Lake Belle View would be drained so that the material can be spread uniformly to design grades in the wetland areas.

9.4 Sediment Removal

Borings indicate that the material to be dredged both within Lake Belle View and the Sugar River consists largely of sands, especially at depths below 2 to 4 feet. The most cost-efficient way to move sand is by hydraulic dredging. These sands would be placed at the borrow site after the site has been utilized for complete construction of the diversion berm. Since the material would consist largely of sand, the placement site would be sized to accommodate a 1:1 ratio of dredge volume to placement volume.

If a confinement structure is necessary to contain the sands within a specific area, they would be built in the same manner as the diversion berm, with cohesive materials taken from the borrow site. These structures would be semi-compacted and built with 2H:1V embankment slopes in accordance with EM 1110-2-5027: Confined Disposal of Dredged Material. The northern stem of the diversion berm would form one side of the confinement structure, as shown in main report plates. The height of the confinement structure is not expected to exceed 7 feet.

Dredge cut stability is also a design consideration. Non-uniform, or "stepped," dredge cuts and associated minor surface sloughing are expected to occur during dredging of the deepwater habitat. However, "stepped" dredge cuts are not expected to affect the overall stability of the deepwater habitat slopes. The overall slope of the cuts would be limited 3H:1V to minimize sloughing. As previously mentioned, the cuts necessary to deepen the Sugar River channel where the diversion berm is considered a dam by Wisconsin definition would have 5H:1V slopes and be protected with 400-lb top size stone.

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